ADST-II-CDRL-NGRXUVII-9900221

27 September 1999

ADVANCED DISTRIBUTED SIMULATION TECHNOLOGY II (ADST II)

Next Generation Reconnaissance Experimental Unmanned Vehicle (NGRXUV) Experiment II

DO #111

CDRL AB01

Final Report

DID: (DI-MISC-80711)

For:

United States Army
Simulation, Training, and Instrumentation Command
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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	27 SEPT 1999	FINAL

4. TITLE AND SUBTITLE
Advanced Distributed Simulation Technology II (ADST-II) Next Generation Reconnaissance Experimental Unmanned Vehicle (NGRXUV) Experiment II Final Report

5. FUNDING NUMBERS
N61339-96-D-0002

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER
ADST-II-CDRL-NGRXUVII-9900221

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

NAWCTSD/STRICOM
12350 Research Parkway
Orlando, FL 32328-3224

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
CDRL AB01

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 Words)*** The Next Generation Reconnaissance & Experimental Unmanned Vehicle II (NGR&XUV) was an experimental exercise conducted at the Mounted Warfare Test Bed (MWTB) at Fort Knox, KY from July 12 to September 1, 1999. The experiment was performed as Delivery Order (DO) #111 under the Lockheed Martin Advanced Distributed Simulation Technology II (ADST II) Contract administered by the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM). The experiment was sponsored by two Government agencies: the Government's Concerted Technology Thrust (CTT) for the Office of the Secretary of Defense's Robotics Demonstration, and the Mounted Maneuver Battle Lab (MMBL), Fort Knox, KY.

14. SUBJECT TERMS
STRICOM, ADST-II, NGR&XUV, MWTB, MMBL

15. NUMBER OF PAGES
20

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

Document Control Information

Revision	Revision History	Date
	Original release	9/27/99
-		
-		
-		
-		
-		
-		
-		
-		
-		
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Executive Summary

The Next Generation Reconnaissance & Experimental Unmanned Vehicle II (NGR&XUV) was an experimental exercise conducted at the Mounted Warfare Test Bed (MWTB) at Fort Knox, KY from July 12 to September 1, 1999. The experiment was performed as Delivery Order (DO) #111 under the Lockheed Martin Advanced Distributed Simulation Technology II (ADST II) Contract administered by the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM). The experiment was sponsored by two Government agencies: the Government's Concerted Technology Thrust (CTT) for the Office of the Secretary of Defense's Robotics Demonstration, and the Mounted Maneuver Battle Lab (MMBL), Fort Knox, KY.

The NGR&XUV Program is an Advanced Concepts and Requirements (ACR) technology base project which plans to examine the characteristics and requirements for a robotics technology and its effectiveness in support of mounted maneuver warfare. NGR&XUV Demonstrations I and II were successful in demonstrating autonomous control and robotics operations. Demonstration II demonstrated its capabilities as a surrogate scout in a live experiment. Demonstration III (the current program) has planned for execution during FY97-02 Programmed Out-year Money (POM) cycle.

The NGR&XUV efforts conducted at the MWTB are multi-year-phased efforts conducted in support of Demonstration III. These efforts started in July of 1997 with Constructive Simulation (CS) I. This effort, Constructive Simulation II and Virtual Simulation (VS) I, used Modular Semi-Automated Forces (ModSAF) as well as man in the loop simulation. CS II and VSI involved the development of new ModSAF behaviors; required executing a ModSAF generated XUV, and focused on soldier in the loop issues in conjunction with the emerging results of the constructive simulations.

The purpose of the Experimental Unmanned Vehicle (XUV) experiment (the main experiment in the overall NGR&XUV effort) was to evaluate the effects on command and control and operational performance with addition of the XUV to the Battalion Task Force (TF) scout platoon and the Brigade Reconnaissance Troop. The experiment used Modular Semi-Automated Forces (ModSAF) to compare baseline organizations of the TF scout platoon and the Brigade Reconnaissance Troop implemented with various sensor packages. Data measures captured the target detection/reporting functions of the scout elements and operational performance of the TF and Brigade Combat Team.
This was the last simulation exercise prior to the Live Demonstration III that was conducted in September 1999.

The experiment will provide the Army with: insights on the relative impact on operational performance of the TF scout platoon and the Brigade Reconnaissance Troop when equipped with XUV in scout operations; insights into the design of the optimum soldier-machine interface; development of Tactics, Techniques, and Procedures (TTPs); and insights into the requirements for development of training support packages. This experiment will also provide objective and subjective findings, which will form the basis for future integration and development decisions, model improvements, and further experimentation.

The objectives of this experiment were to determine if unmanned systems provide:

- Increased situational awareness through detection, recognition, and identification.
- Increased survivability to manned platforms.
- Increased Battlespace by providing more complete information on the location and status of hostile and unknown elements at any given time or place.
- Increased tempo by allowing the commander to make timely decisions based on real time and

highly accurate information.

- Increased mobility and the capability to move about the Battlespace. Detect, acquire, identify and designate fixed and mobile targets.
- The communications requirements of unmanned vehicles in a combat environment.

The experiment included baseline, XUV with the Operator Control Unit (OCU) and Semi-Autonomous Reconnaissance Operations (SARO) trials. The purpose of the SARO portion of this experiment was to evaluate the effects on control and operational performance with addition of a variety of semi-autonomous technologies to the reconnaissance operations of the Battalion Task Force (TF) scout platoon and the Brigade Reconnaissance Troop.

The experiment's test trial window was separated into Phases A and B. Phase A was from July 12-23 and Phase B was from August 18 – September 1. All phases were completed ahead of schedule. The remaining time in Phase A was allocated for excursion runs. No excursion runs were made in Phase B.

Also in accordance with the Government SOW, this Final Report includes a description of the experiment, its conditions and conduct, and lessons learned. This report addresses the interconnectivity of simulation systems, modifications to ModSAF and the manned simulators, and the integration of Government Furnished software models. This report does not include discussion of data analysis nor conclusions as to whether the customer(s) achieved the objectives of the experiment.

1.0 INTRODUCTION

1.1 Purpose

The purpose of this final report is to document the ADST II effort, which supported NGR-XUV II, Delivery Order (DO) #0111. This report includes a full description of the experiment, its conditions, and lessons learned.

1.2 Contract Overview

The Next Generation Reconnaissance & Experimental Unmanned Vehicle (NGR&XUV) was an experimental exercise conducted at the Mounted Warfare Test Bed (MWTB) at Fort Knox, KY from July 12 to September 1, 1999. The experiment was performed as Delivery Order (DO) #111 under the Lockheed Martin Advanced Distributed Simulation Technology II (ADST II) Contract administered by the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM). The experiment was sponsored by two Government agencies: the Government's Concerted Technology Thrust (CTT) for the Office of the Secretary of Defense's Robotics Demonstration, and the Mounted Maneuver Battle Lab (MMBL), Fort Knox, KY.

1.3 Experiment Overview

The NGR&XUV efforts conducted at the MWTB are multi-year-phased efforts conducted in support of Demonstration III. These efforts started in July of 1997 with Constructive Simulation (CS) I. This effort, Constructive Simulation II and Virtual Simulation (VS) I, used Modular Semi-Automated Forces (ModSAF) as well as man in the loop simulation. CS II and VSI involved the development of new ModSAF behaviors; required executing a ModSAF generated XUV, and focused on soldier in the loop issues in conjunction with the emerging results of the constructive simulations.

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The experiment will provide the Army with: insights on the relative impact on operational performance of the TF scout platoon and the Brigade Reconnaissance Troop when equipped with XUV in scout operations; insights into the design of the optimum soldier-machine interface; development of Tactics, Techniques, and Procedures (TTPs); and insights into the requirements for development of training support packages. This experiment will also provide objective and subjective findings, which will form the basis for future integration and development decisions, model improvements, and further experimentation.

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- Increased survivability to manned platforms.

- Increased Battlespace by providing more complete information on the location and status of hostile and unknown elements at any given time or place.
- Increased tempo by allowing the commander to make timely decisions based on real time and highly accurate information.
- Increased mobility and the capability to move about the Battlespace. Detect, acquire, identify and designate fixed and mobile targets.
- The communications requirements of unmanned vehicles in a combat environment.

1.4 Technical Overview

The technical approach to the NGR&XUV Experiment initially involved an analysis of the results of the previous XUV efforts and a requirement analysis of the OCU for the projected fielded system for implementation into the simulation exercise. The initial plan called for the initial development and integration of the OCU software to be developed and the Operational Support Facility (OSF) in Orlando, Florida. After the initial development of software products was complete, the software would be shipped to the OSF for further integration and then on to the MWTB for final integration. Upon completion of integration effort at the MWTB functional tests were conducted. Once the synthetic environment functional tests were completed, approval was given to proceed with the experiment. Each phase of the experiment started with two days of training by the MWTB staff, followed by the remaining days being allocated to experiment trials. A detailed discussion of Phases A and B are discussed in detail later in this document.

2.0 Applicable Documents

2.1 Government

- ADST II Work Statement for Next Generation Unmanned Vehicle II (NGUV), 16 February 1999, AMSTI-99-WO11, Version 1.0

- Battle Lab Experiment Plan (BLEP) for Experimental Unmanned Vehicle (XUV), and Semi-Autonomous Reconnaissance Operations (SARO) Virtual II Simulation, Mounted Warfare Testbed and Mounted Maneuver Battlespace Lab, ATZK-MW, Fort Knox, Kentucky, 17 May 1999

2.2 Non-Government

3.0 System Description

3.1 System Configuration and Layout

The MWTB contains variety of simulators, networks, ModSAF capabilities, displays for monitoring the battlefield, utilities to facilitate exercises, and automated data collection and reduction capabilities. The NGRXUV Network Diagram is shown at Figure 1 and the complete list of network addresses and associated system components is at Appendix A.

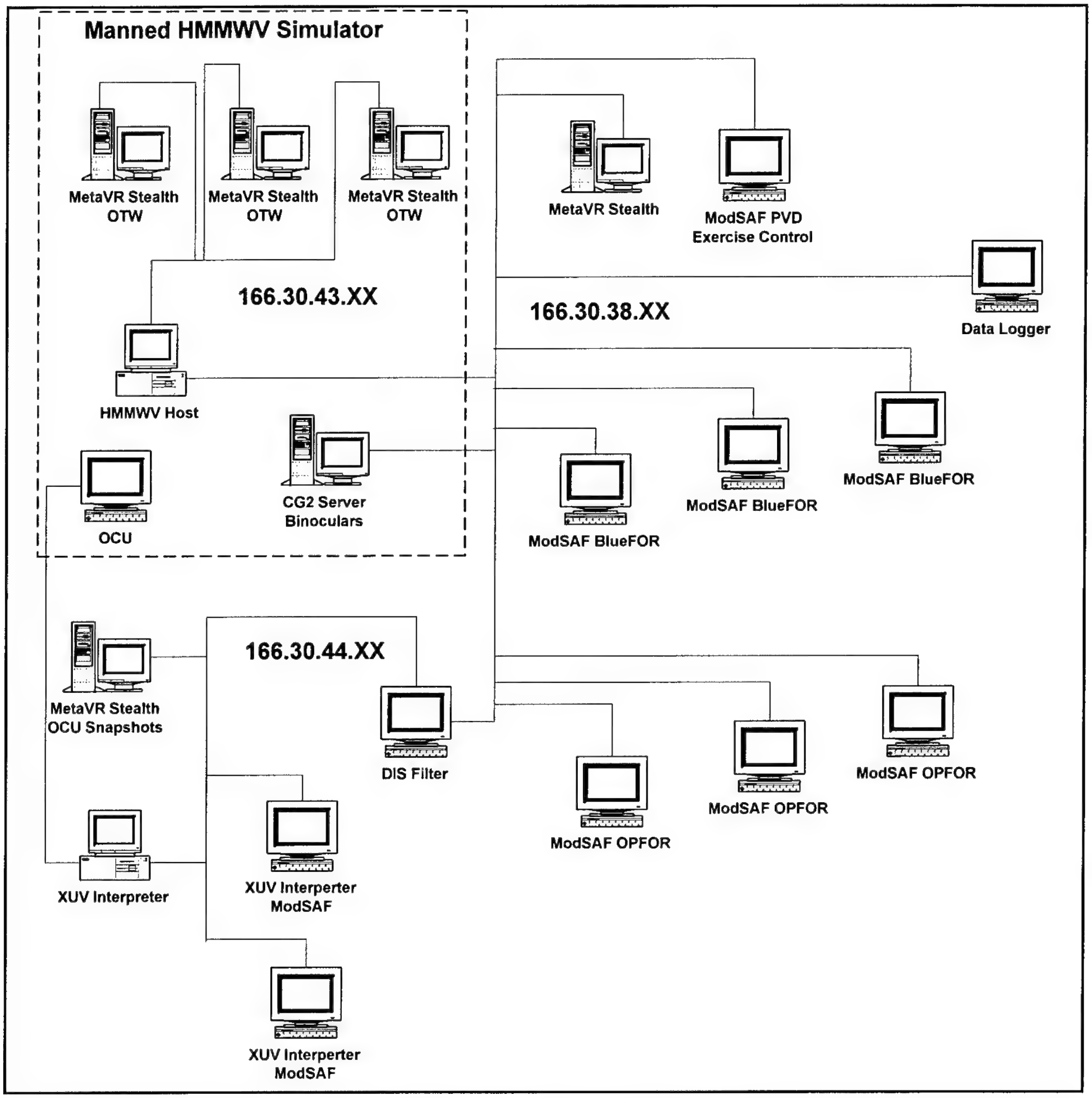

Figure 1 NGR-XUV Network Diagram

3.2 *Description of System Components*

This section discusses the description, functionality and operation of the system components, which includes the OCU, XUV Interpreter, ModSAF, Data Logger and stealth applications. A complete listing of system components can be found in Appendix A.

3.2.1 Operator Controller Unit (OCU)

The OCU provided the XUV controller a graphical user interface (GUI) for issuing commands to up to four XUVs and displaying tactical information obtained by the XUVs and other friendly forces. The OCU gui included a terrain map and several modes to plan and execute missions. The terrain data translated from ModSAF's compact terrain database was obtained from ARL at the Aberdeen

Proving Grounds. The OCU modes included tools to obtain information about the terrain, a method to draw various mission graphics on the map, a way to establish the command connection between the OCU and the XUVs, and a mission planning tool suite.

The OCU hardware included a high end PC and a touch panel flat screen display. This display was similar to the OCU that will be used for the live XUV demo in September. The original OCU software was developed in Denver. Technical exchange meetings were conducted in Orlando and Denver. Final integration was completed on site via installation of patches from Denver. Because the real XUV will use Neutral Message Language (NML) to communicate with the OCU and NML did not support Solaris86 , the OCU operating system (OS) was Linux.

3.2.2 XUV Interpreter

The XUV Interpreter was a translator between the NML network traffic of the OCU and the DIS traffic of the ModSAF XUVs. NML commands from the OCU were converted into experimental DIS PDUs for the ModSAF XUVs. XUV DIS PDU reports were rendered into NML packets. A stealth was also used to provide images from the XUV visual sensors. When the ModSAF XUVs spotted an enemy vehicle, an experimental DIS stealth request PDU was sent to the stealth. New MetaVR software repositioned the stealth, captured the image, and placed the bmp file on the XUV interpreter through a remote mounted directory. The XUV interpreter then converted the bmp file to the jpeg format used by the OCU. If an NML image request was received for that vehicle, the image was remotely copied to the OCU through Linux commands embedded in the software. A TIREM radio model was used to check if messages sent to or from the OCU should be received. Situation awareness of the OCU host vehicle and OPFOR vehicles spotted by friendly forces other than the XUVs was also provided to the OCU.

3.2.3 Modular Semi-Automated Force (ModSAF)

Except for the host OCU vehicle, ModSAF was used to simulate both the BLUFOR and OPFOR units and vehicles. The baseline version was ModSAF 4.0. This release has been greatly enhanced by MWTB staff and others from previous experiments conducted on site. The XUV behaviors developed for previous experiments were also used with minor changes. A new ModSAF library was developed to control and respond to these behaviors. When experimental DIS PDU commands were received they were decoded and the appropriate behavior was executed. When the behaviors generated XUV reports, experimental DIS PDU reports were sent to the XUV interpreter.

3.2.4 Manned HMMWV Simulator

The gunner is either riding in the back seat or standing up to look out the hatch. While seated, he can look past the driver at the screens, and while standing he can get a better view at the screens or use his binoculars to get 360 degrees Field Of View (FOV) head tracker controlled. A Cal 50 gun is mounted on top of the vehicle, and can be used to engage area targets on the screen. The gun feeds serial data about the gun azimuth and elevation, as well as the trigger to the host. The driver will be able to view the out-the-Hatch view from his position. This gives him approximately 136 degrees FOV. The speedometer, fuel gauge, gear indicator, steering wheel, accelerator pedal and brake pedal are all operational and are controlled through a descrete I/O card located on the host.

The commander sits in the passenger seat and has the Liquid Crystal Diode (LCD) touchscreen mounted in front of him. The commander also has use of a SimPhonics dual panel SINCGARS radio simulation to maintain radio contact with their commander.

3.2.5 Data Logger

The Data Logger is an ADST II asset that captures the network traffic and places the data packets on a disk or tape file. The Data Logger performs the following functions:

a. Packet Recording - Receives packets from the DIS network time stamps and then writes to a disk or tape.

b. Packet Playback - Packets from a recorded exercise can be transmitted in real time or faster than real time. The Data Logger can also suspend playback (freeze time) and skip backward or forward to a designated point in time. The logger can be controlled directly from the keyboard or remotely from the Plan View Display (PVD). Playback is visible to any device on the network (PVD, Stealth Vehicle, a vehicle simulator, etc.).

c. Copying or Converting - Files are copied to another file, which can be on the same or a different medium; and files from the older version of the Data Logger can be converted to a format compatible with the current version of the Data Logger.

3.2.6 IRIG Time Stamper

The Simulation LANs were time synchronized using an Inter-Range Instrumentation Group (IRIG) timecode signal generator, two SUN IPXs and an IRIG Signal Conditioner. The signal generator's output was fed into the signal conditioner which cloned the amplitude-modulated 1000 Hz sinewave signal, passing it on to as many as four SUN workstations. These workstations, utilizing a modified Berkeley Standard Distribution (BSD) audio driver and Network Transfer Protocol (NTP), acted as the time servers for their respective LANs, resulting in time synchronized sub LANS.

4.0 Conduct of the Experiment

4.1 Troop Training

Troop training for manned crew was conducted on July 7-9, for the first set of trials and on August 18-19 for the second set of trials. The commander was trained on OCU operation and mission conduct for the experiment. The driver and gunner were trained on use of the HMMWV simulator including the driving controls, machine gun and binoculars.

4.2 Pilot Test

A formal Pilot Test was not conducted. However, an intensive stress of the OCU was conducted for the customer on August 9 to ensure that the hardware and software was ready for the second set of trials or Phase B which started on August 18. The stress test of the OCU conducted on August 9th encompassed both primary trial scenarios. During this test, it was noted by the principle investigator that operator error was a factor in negative OCU performance. Repeated like commands inputted by the operator prior to execution of the initial command caused the OCU to lock. This problem was alleviated by remedial operator training and noted to the Training Support Package (TSP) prepotency by the Principle Investigator. Upon completion of repeated trials, the OCU successfully completed all required tasks in both primary Scenarios.

4.3 Experiment and Trial Runs

The experiment had two phases of trial runs. The configurations were; Baseline, Semi Autonomous Reconnaissance Operations (SARO) and XUV. The Scenarios were; Movement to Contact (MTC) and Stability and Security Operations (SASO). Phase A was conducted from July 12th-23rd. The

Trial Run Matrix is shown below in Table 1.

Trial No.	Trial Set	Scout Configuration	Scenario	
1	B	Baseline	MTC	
27	B	SARO	SASO	
21	B	SARO	MTC	
18	B	XUV	SASO	
7	B	Baseline	SASO	
10	B	Baseline	SASO	
11	B	XUV	MTC	
6	B	Baseline	SASO	
12	B	XUV	MTC	
22	B	SARO	MTC	
24	B	SARO	MTC	
3	B	Baseline	MTC	
15	B	XUV	MTC	
19	B	XUV	SASO	
14	B	XUV	MTC	
4	B	Baseline	MTC	
9	B	Baseline	SASO	
13	B	XUV	MTC	
30	B	SARO	SASO	
20	B	XUV	SASO	
25	B	SARO	MTC	
2	B	Baseline	MTC	
5	B	Baseline	MTC	
26	B	SARO	SASO	
28	B	SARO	SASO	
17	B	XUV	SASO	
8	B	Baseline	SASO	
23	B	SARO	MTC	
29	B	SARO	SASO	
16	B	XUV	SASO	
1XX	B	SARO	MTC	*
2XX	B	SARO	SASO	*
3XX	B	Baseline	MTC	*
4XX	B	Baseline	SASO	*
5XX	B	SARO	MTC	*
6XX	B	SARO	SASO	*
7XX	B	Baseline	MTC	*
8XX	B	Baseline	SASO	*

Table 1 July Trial Run Matrix

* Indicates additional trials added by PI

OCU Trials Attempted and retried to no avail.

Phase B was scheduled from August 18th to September 1st, and ended two days ahead of schedule on

August 30th. The August Trial Run Matrix is shown below in Table 2.

Trial No.	Trial Set	Scout Configuration	Scenario	
31	C	Baseline	MTC	
32	C	Baseline	MTC	
33	C	Baseline	MTC	
34	C	Baseline	MTC	
35	C	Baseline	MTC	
36	C	Baseline	SASO	
37	C	Baseline	SASO	
38	C	Baseline	SASO	
39	C	Baseline	SASO	
40	C	Baseline	SASO	
44	C	XUV	MTC	
42	C	XUV	MTC	
43	C	XUV	MTC	
44	C	XUV	MTC	
45	C	XUV	MTC	
46	C	XUV	SASO	
47	C	XUV	SASO	
48	C	XUV	SASO	
49	C	XUV	SASO	
50	C	XUV	SASO	
51	C	SARO	MTC	
55	C	SARO	MTC	
53	C	SARO	MTC	
54	C	SARO	MTC	
55	C	SARO	MTC	
56	C	SARO	SASO	
57	C	SARO	SASO	
58	C	SARO	SASO	
59	C	SARO	SASO	
60	C	SARO	SASO	

Table 2 August Trial Run Matrix

5.0 Observations and Lessons Learned

- Observation #1

There was repeated difficulty in coordinating the development efforts between the OCU and the XUV Interpreter.

- Discussion #1

The schedule of the development cycle of the XUV Interpreter was disrupted because of

dependencies on the development of the OCU and its components. The decision to use the Neutral Message Language (NML), while appropriate for use with the actual robot forced the integration of an unknown component into the system late in the development phase. In addition the development of the OCU and robot were on a separate schedule as the development of the Interpreter and simulation components. This resulted in conflicts of scheduling and more importantly, engineering resources during the development cycle.

- Lesson Learned #1

In order for Simulation Based Acquisition (SBA) to be effective it needs to be a tightly integrated part of the overall effort. Because the simulation effort was ancillary to the development of the live system the ability to produce significant contributions from the simulation effort was limited.

- Observation #2

Requiring the simulation effort to use the actual OCU resulted in engineering issues from the development of the OCU effect the development of the Interpreter.

- Discussion #2

Because the developers of the OCU had the primary priority of deploying a working system with the live vehicle, their ability to support the Simulation Based Acquisition (SBA) was limited. In addition software baselines were not coordinated between the two efforts which resulted in a arbitrary deadline where support was no longer possible because of changes in the OCU code to support the live test.

- Lesson Learned #2

Better coordination between the development schedules would have enhanced the ability of the simulation effort to contribute to the overall effort. One possible solution would be to finish the simulation phase before the prototyping of the initial vehicle was started.

- Observation #3

It was difficult to anticipate all the network problems encountered in the final on site integration

- Discussion #3

The relationship between the OCU, XUV Interpreter, MetaVR steath, and ModSAF was complex. NML and DIS were two vastly different network communication protocols. NML messages were sent from the OCU to the XUV Interpreter through multiple dual command buffers for each XUV. Experimental DIS PDUs were sent from the interpreter to the stealth and ModSAF. The stealth used underlying network tools to send the image to the interpreter. ModSAF sent experimental DIS PDUs to the interpreter. The XUV Interpreter sent NML messages back to the OCU. A separate NML buffer was used for situation awareness. All this took place over the network while DIS entity state PDUs and experimental spotted PDUs were on line from all the vehicles in the exercise. This resulted in multiple network problems that had to be resolved on site.

- Lesson Learned #3

In order to shorten the on site integration time, the conditions on site should be duplicated as close as possible at the software development and testing location.

6.0 Conclusion

The NGR&XUV II experiment accomplished it's primary goal which was to evaluate a concept which would redefine future concepts and requirements with the use of robotics to enhance the decision making capability for the Commander and his staff in the future. The success of this initial

effort has resulted in the approval and expansion for additional evaluations to further redefine these requirements. Currently two more experiments are scheduled in the next twelve months. These future experiments are currently the number one priority of the Fort Knox Battle Lab.

7.0 Points of Contact

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STRICOM

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8.0 Acronym List

AAR	After Action Review
ADST	Advanced Distributed Simulation Technology
BLUFOR	Blue Forces
BSD	Berkeley Standard Distribution
C2	Command and Control
CDF	Core DIS Facility
CDRL	Contract Data Requirements List
DO	Delivery Order
DIS	Distributed Interactive Simulation
FOV	Field Of View
GFE	Government Furnished Equipment
HMMWV	High Mobility Motorized Wheeled Vehicle
IO	Input/Output
IRIG	Inter-Range Instrumentation Group
LAN	Local Area Network
LCD	Liquid Crystal Diode
ModSAF	Modular Semi-Automated Forces
MMBL	Mounted Maneuver Battle Lab
MTC	Movement to Contact
MWTB	Mounted Warfare Test Bed
NGRXUV	Next Generation Reconnaissance Experimental Unmanned Vehicle
NML	Neutral Message Language
NTP	Network Transfer Protocol
OCU	Operator Control Unit
OPFOR	Opposing Forces
OSF	Operational Support Facility
PC	Personnel Computer
PDU	Protocol Data Unit
PI	Principle Investigator
PM	Program Manager

PO	Persistent Object
POC	Point of Contact
POM	Programmed Out Year
POP	Persistent Object Protocol
PVD	Plan View Display
SAF	Semi-Automated Forces
SARO	Semi Autonomous Reconnaissance Operations
SASO	Stability and Security Operations
SBA	Simulation Based Acquisition
TF	Task Force
TTP	Tactics Techniques and Procedures
XUV	Experimental Unmanned Vehicle